

# THE IMAGING X-RAY POLARIMETRY EXPLORER

An Overview

Martin C. Weisskopf & Stephen L. O'Dell  
On behalf of the IXPE Team

# Directly Participating Institutions

## Institutions:

- MSFC- PI Team, Project Management, Systems Engineering, Oversight, Science Operations, Data Analysis and Archiving, Telescope Fabrication, and X-ray Calibration
- Istituto di Astrofisica e Planetologia Spaxiale (Rome) & Istituto Nazionale di Fisica Nucleare (Pisa) – Polarization-sensitive detectors
- Ball Aerospace – Spacecraft, Payload Electronics, Payload Structure, Payload and Observatory I&T
- Laboratory for Astronomy and Space Physics (Boulder) – Mission Operations
- Stanford university & Univ Roma Tre – Theory

# Science Team

Martin Weisskopf (MSFC) – PI  
Brian Ramsey (MSFC) – Deputy PI and Payload Scientist  
Stephen O'Dell (MSFC) – Project Scientist  
Allyn Tennant (MSFC) – Science Data Ops Lead  
Paolo Soffita (IAPS, IT) – Co-I and PI for Italian effort  
Ronaldo Bellazzini (INFN, IT) – Co-I and PI for INFN effort  
Victoria Kaspi (McGill, Can) – Co-I SWG Chair  
Herman Marshall (MIT) – Co-I and Student Collaboration Scientist  
Giorgio Matt (Univ Roma Tre, IT) – Co-I Theory  
Roger Romani<sup>1</sup> (Stanford) – Co-I Theory

# Collaborators

## Unfunded

N. Bucciantini, N. Bucciantini, E. Churazov, M. Dovciak, R. Goosmann,  
S. Gunji, *V. Karas*, D. Lai, G. Pavlov, P. Petrucci,  
J. Poutanen, M. Salvati, L. Stella, R. Sunyaev,  
R. Turolla, K. Wu, S. Zane

## Contributed (INFN)

A. Brez, G. Spandre, L. Baldini, C. Sgrò, N. Omodei,  
L. Latronico, M. Minuti, M. Pinchera, L. Deruvo, M. Kuss, M. Pesce-Rollins  
M. Razzano

## Contributed (IAPS)

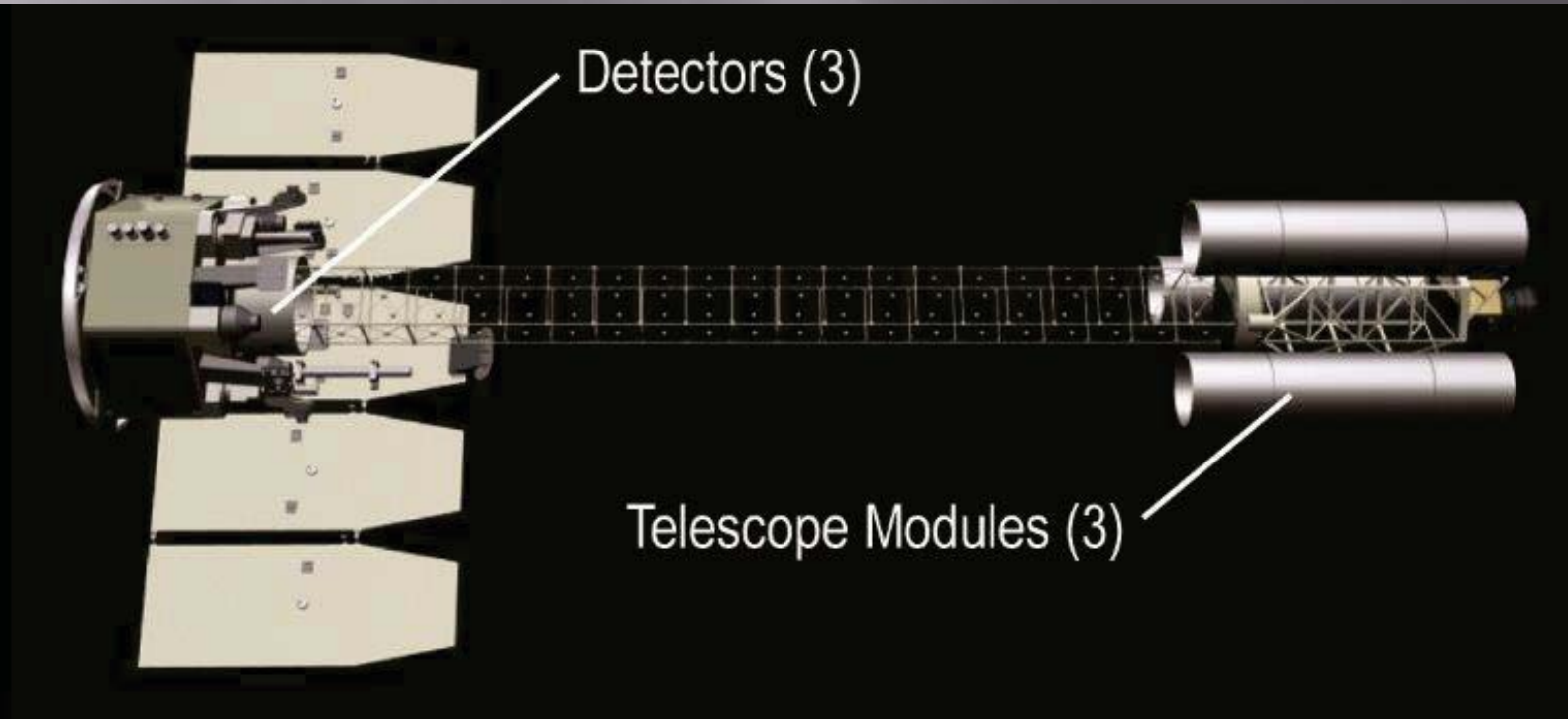
E. Del Monte, I. Donnarumma, S. Fabiani, L. Pacciani, A. Rubini

# Mature Technology Plus an Experienced Team to Expand the X-ray View of the Universe

- IXPE uses X-ray polarimetry to dramatically expand observation space and to provide new input to our understanding as to how X-ray emission is produced by compact objects such as neutron stars and black holes.
- The two-year mission is low-risk, making use of mature flight elements combined in a system with conservative resource margins and run by a team with extensive mission experience, specifically in X-ray astronomy and X-ray polarimetry

# Approach

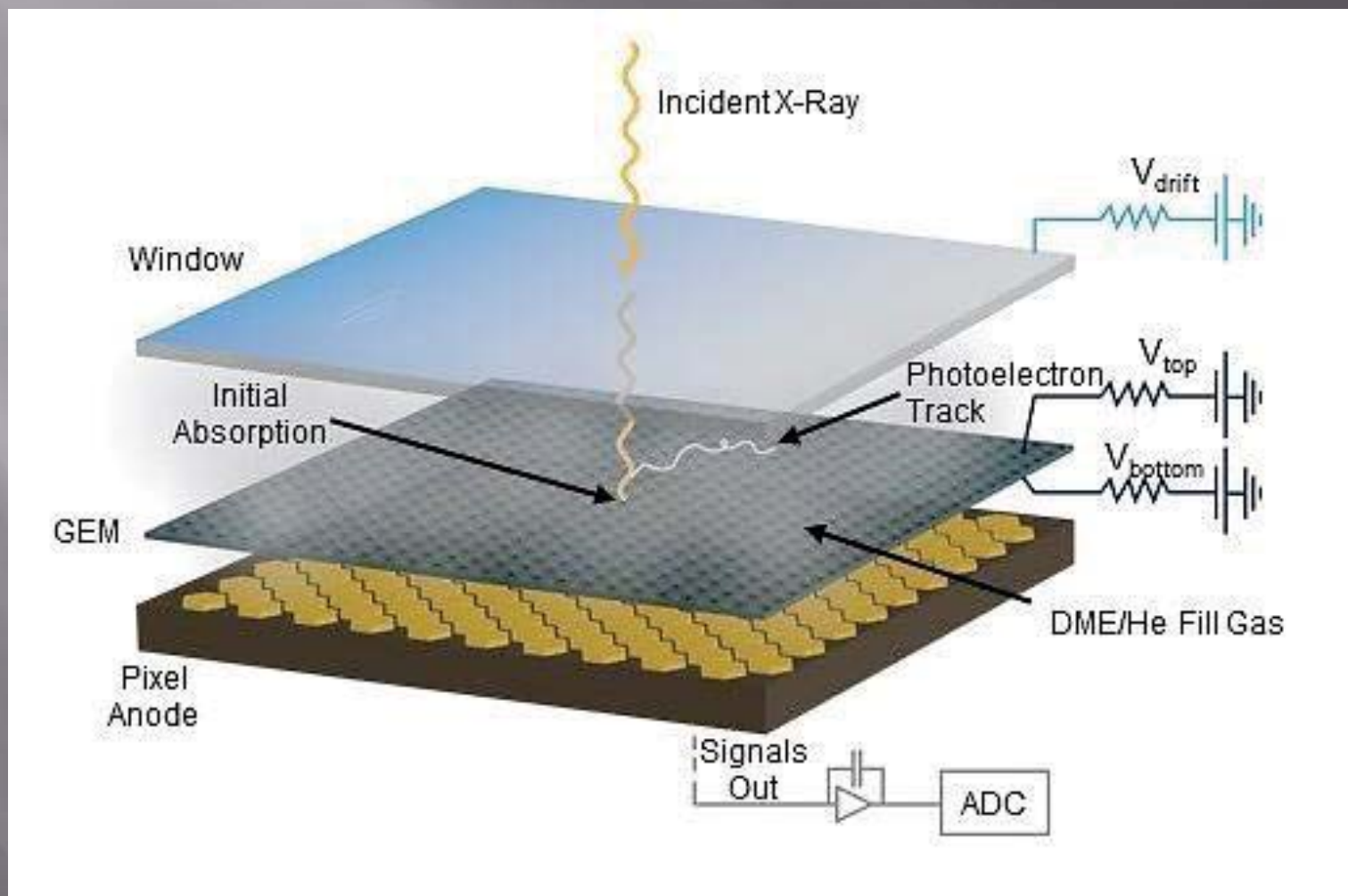
- Three redundant telescope-detector systems
- Gas pixel electron tracking detectors developed in Italy
- Replicated X-ray telescopes with  $< 30$  arcsecond angular resolution (half-power diameter) developed at MSFC





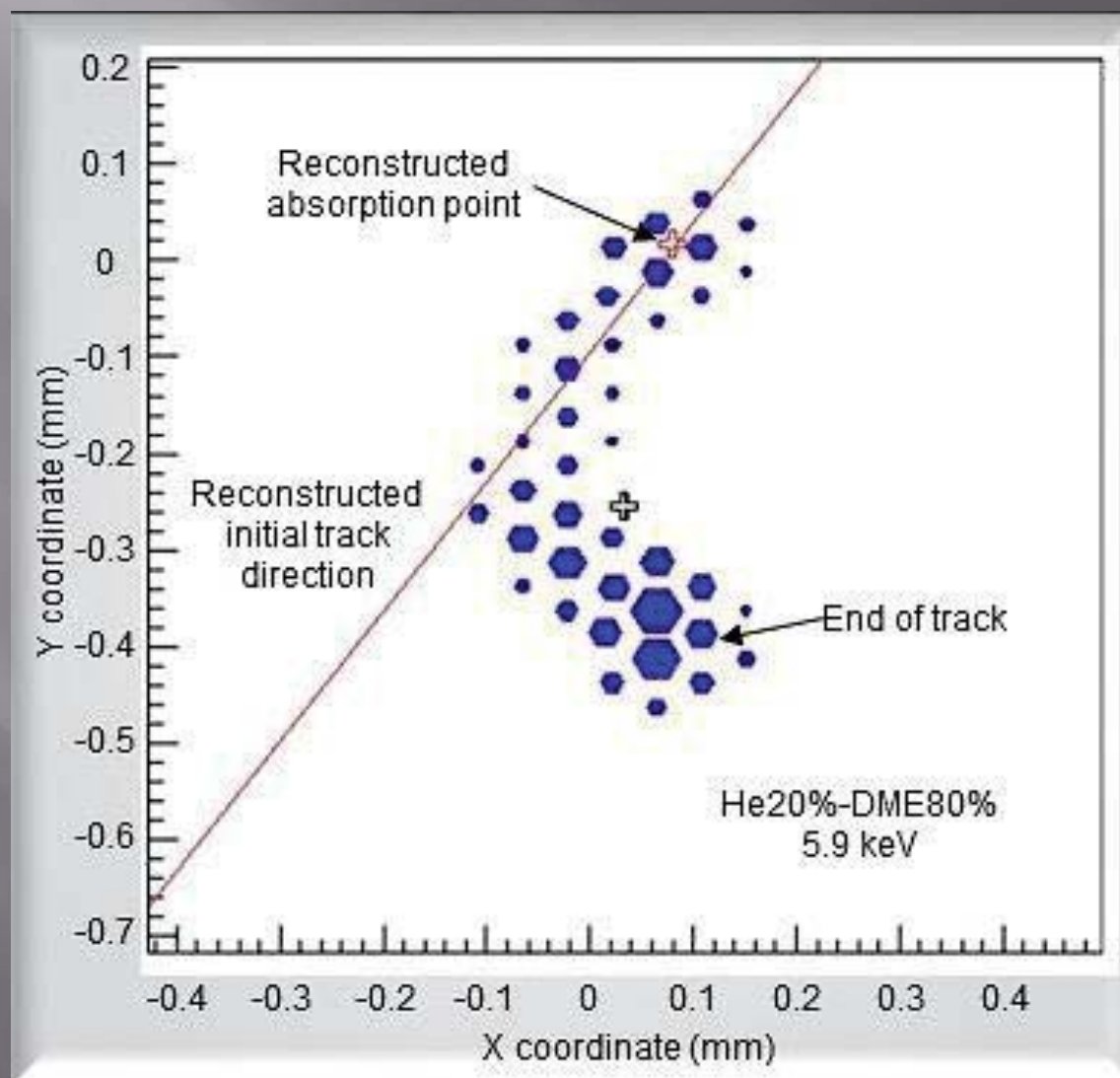
# The Polarization Sensitive Detectors

Gas pixel electron tracking detectors developed in Italy



# The Polarization Sensitive Detectors

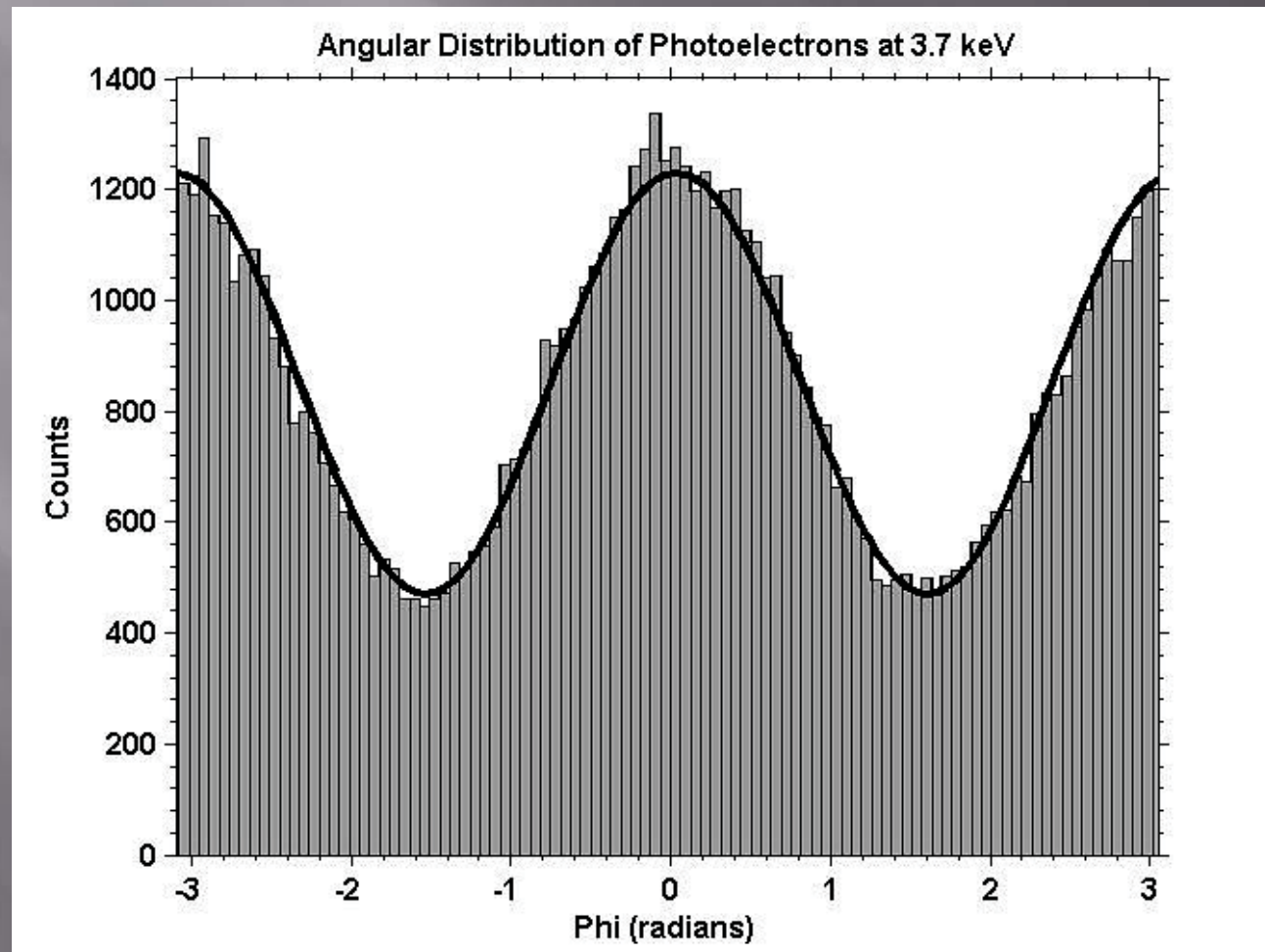
## Track reconstruction





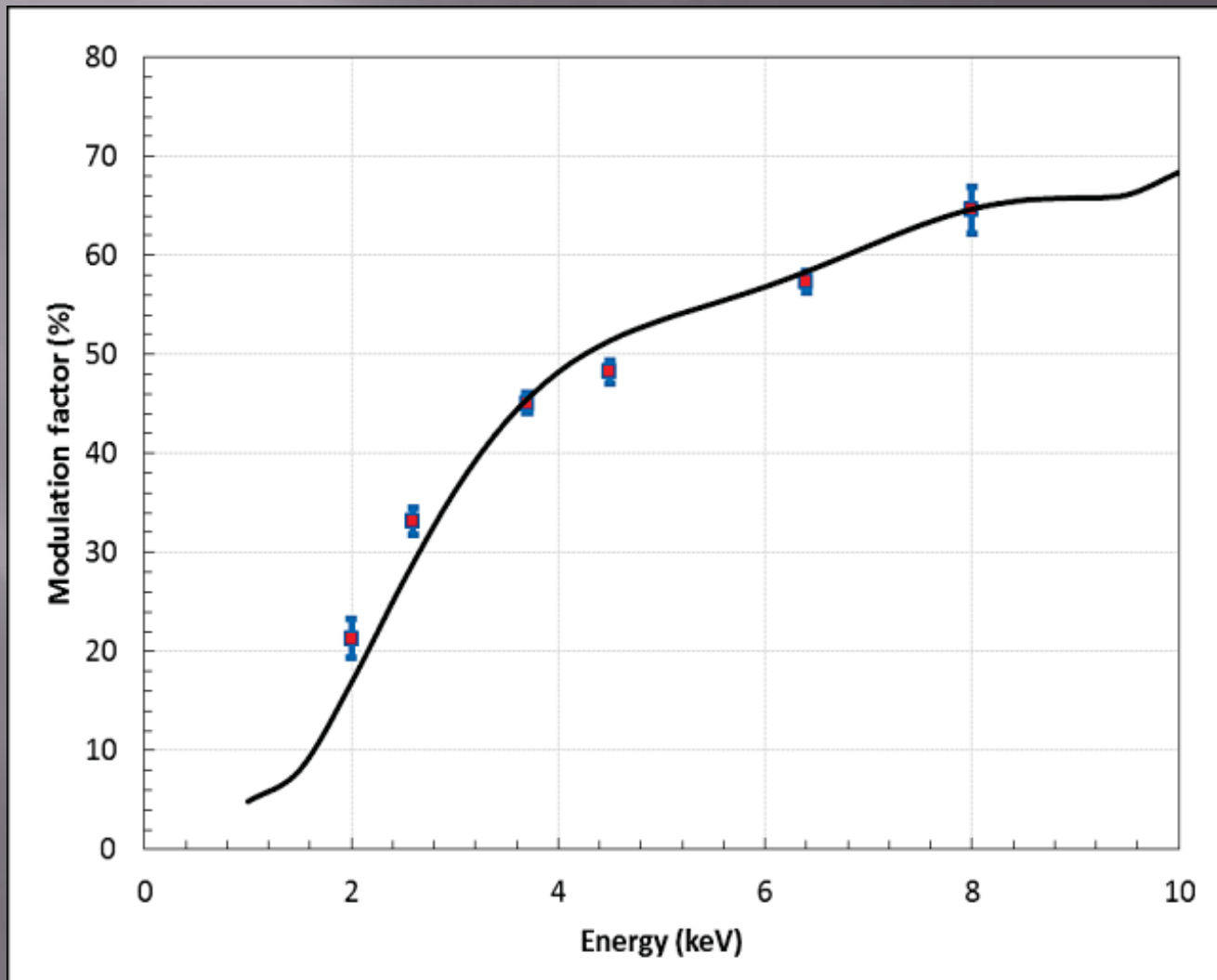
# The Modulation Factor

Measurements of the detector modulation with a 100%-polarized beam at 3.7 keV



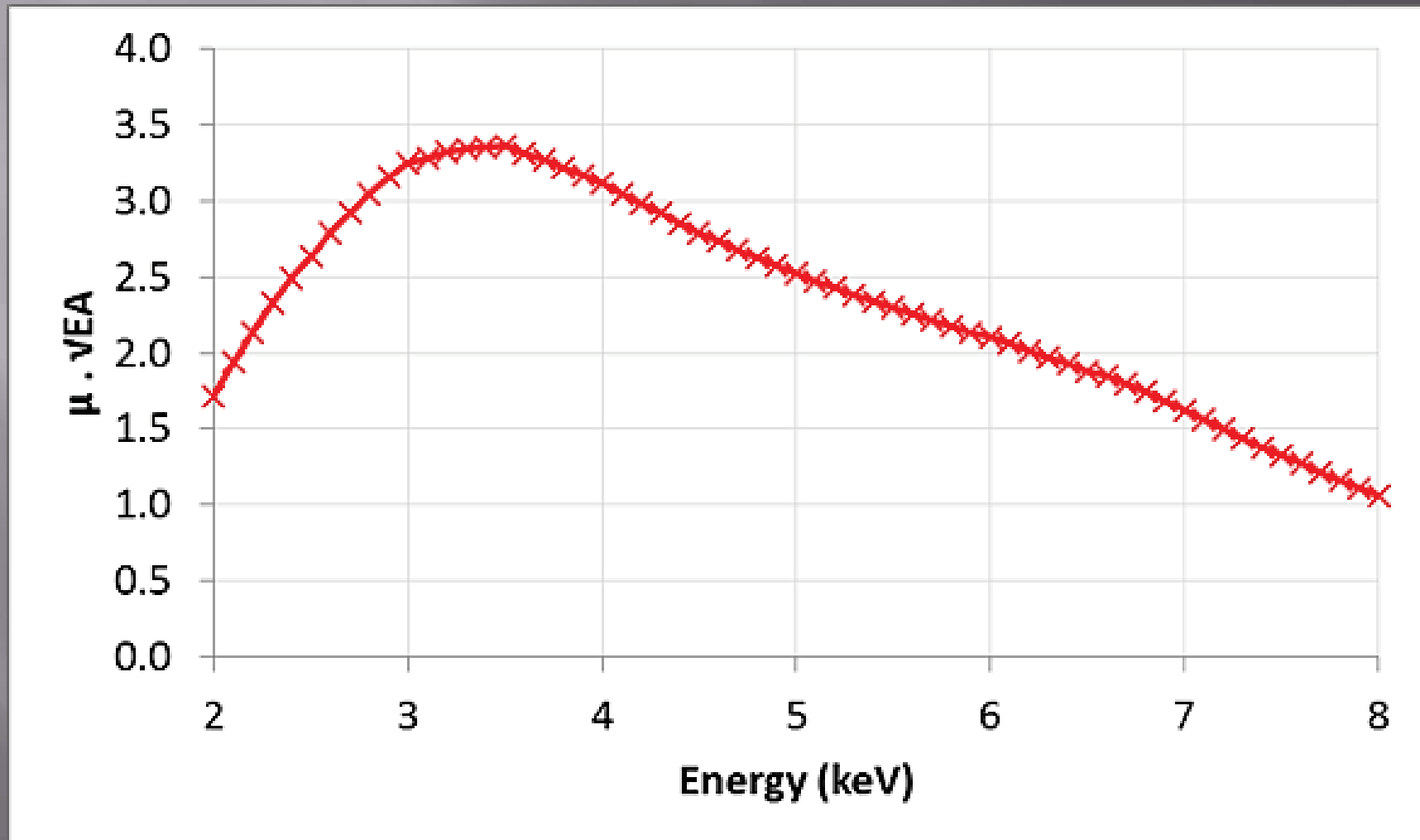
# The Modulation Factor

Modulation factor as a function of energy  
Comparison to simulations



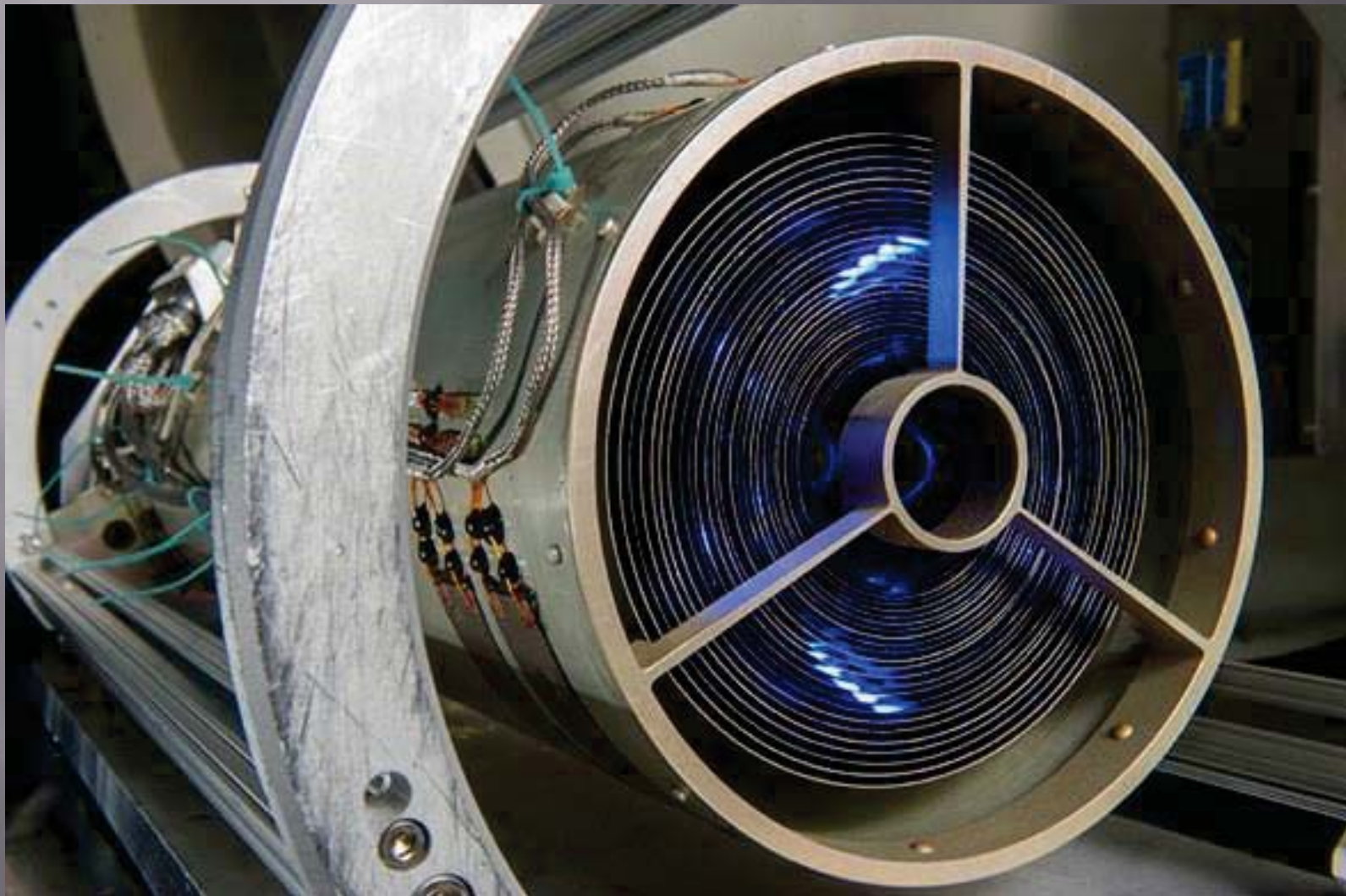
# The Energy Response

Modulation factor  $\times$  square root of the effective area versus energy



# The 25 Arcsecond X-ray Telescopes

An ART-XC flight module in its support frame  
rear view



# The Sensitivity to Polarization

The quantity most useful for assessing the performance of a polarimeter is the minimum detectable polarization (MDP) at 99% confidence, given by:

$$\text{MDP}(\%) = (429/\mu) \sqrt{\frac{R_S + R_B}{R_S^2 t}}$$

$\mu$  = Modulation factor

$R_S$  = Source counting rate

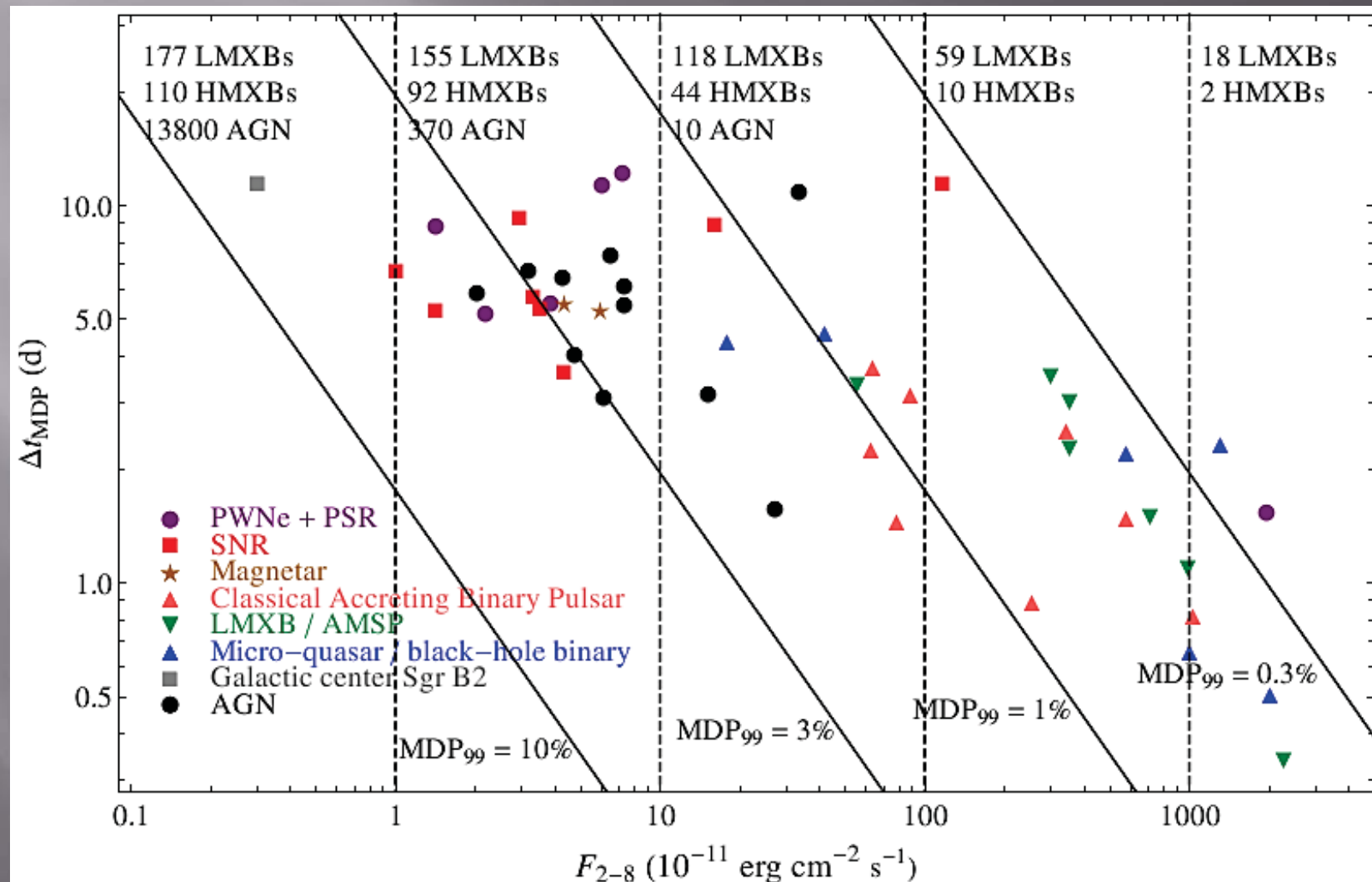
$R_B$  = Background counting rate

$t$  = Integration time



# Sensitivity

Time to reach a minimum detectable polarization as a function of source flux



# FUNDAMENTAL NEW MEASUREMENTS

- IXPE sensitivity is two orders of magnitude better than OSO-8 and provides, for the first time, imaging capability to reach new objectives.
- Measurements with IXPE will provide previously unobtainable data to understand the nature of X-ray sources, helping to answer such questions as:
  - What is the geometry and the emission mechanism(s) of AGN & microquasars?
  - What is the geometry and strength of the magnetic field in magnetars?
  - What is the geometry and origin of the X-radiation from radio pulsars?
  - How are particles accelerated in Pulsar Wind Nebulae?

# FUNDAMENTAL NEW MEASUREMENTS (Examples)

- Obtain X-ray polarimetric images of an AGN core and jet
- Exploit imaging polarimetry to infer past activity of Sgr A\*
- Map magnetic field of X-ray-emitting regions in Pulsar Wind Nebulae and in shell-type Supernova Remnants
- Perform phase-resolved polarimetry of rotation-powered pulsars using imaging to reduce nebular background
- Explore Magnetar physics and vacuum birefringence
- Obtain energy-resolved polarimetry of AGN and microquasars to test models and assess black-hole spin
- Perform phase- and energy-resolved polarimetry of accreting X-ray pulsars to test emission models